

Outcomes of Treatment of Multiple Ligament Knee Injuries

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Abstract

Knee dislocations are rare and potentially devastating injuries. Significant displacement of the tibia and femur commonly disrupts multiple knee ligaments and also often results in profound disruption to the surrounding soft tissue envelope. Open wounds and neurologic and vascular insult can put the involved limb in jeopardy. Following reduction, the optimal management of the dislocated knee is unknown. Surgery to repair and/or reconstruct torn structures likely affords superior long-term function over nonoperative immobilization strategies. The role of early versus delayed surgery, repair versus reconstruction, and autograft versus allograft tissue for reconstruction remain topics of debate. High-quality research efforts to investigate these controversies are hampered by the heterogeneous nature of the injuries themselves and the many treatment strategies available.

Keywords

- ▶ multiple ligament knee injury
- ▶ outcome
- ▶ review

Knee dislocation is a rare but potentially devastating injury. The combination of this relatively low incidence, a variety of ligament injury patterns, and availability of multiple surgical options has made outcomes unpredictable and, unfortunately, incompletely understood.^{1,2} The development of specialized tertiary referral centers in large metropolitan cities has meant that surgeons with both experience and an academic interest in these complex injuries more commonly treat multiligament knee injuries.

The definition of a multiligament knee injury (also, multiple ligament knee injury or MLKI) is commonly recognized as disruption to at least two of the four major knee ligament structures: the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), the posteromedial corner, and the posterolateral corner (PLC).^{3,4} A knee dislocation is typically characterized by rupture of both cruciate ligaments, in combination with either an associated grade III medial or lateral sided injury.⁵⁻⁷ It is likely that the true incidence of these injuries is underestimated, with many

knee dislocations spontaneously reducing prior to presentation.⁴

Schenck described the most widely used classification system for the dislocated knee in 1994, which is based on the anatomical patterns of ligaments torn.^{6,7} The future of research in the multiple ligament injured knee will likely require treatment algorithms for each of the anatomical injury patterns described.²

The optimal treatment of the MLKI is unknown. In 1937, Conwell and Alldredge observed that the ligament damage sustained was so often extensive that closed reduction was preferable to open reduction.⁸ Stiffness was encouraged via prolonged immobilization thereafter. By 1955, O'Donoghue suggested that improved outcomes could be obtained by early surgery to repair damaged structures and facilitate motion more quickly.⁹ The debate between immobilization to promote stiffness and surgery to allow early motion persists, as do other contentious issues, including early versus delayed surgery, repair versus reconstruction, and the use of allograft

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versus autograft.³ Moreover, the presence of associated fractures (tibial plateau, distal femur), vascular injuries, common peroneal nerve injuries, open wounds, and other skeletal and visceral injuries complicate the management of these patients even further.

This review will look at the different options described to treat MLKIs and summarize the reported outcomes. In doing so, we will attempt to highlight the main controversies in this field and outline the future of research in the management of the multiligament knee.

Outcome Measures

Standardized, validated patient-derived outcomes are crucial to assess the impact of injury and treatment while simultaneously minimizing potential bias. Moreover, these measures permit a more uniform comparison of patient groups from different centers and afford an unbiased interpretation of the outcomes of different management protocols. With respect to MLKIs specifically, the injury patterns and associated trauma and treatment options are often extremely heterogeneous amongst individual patients and between treatment centers. This heterogeneity (*noise*) poses particular difficulty when trying to capture patient's response to injury and treatment (*signal*). Commonly employed "knee-specific" measures are designed to more clearly distinguish the impact of knee symptoms on overall function and include the Lysholm and the International Knee Documentation Committee (IKDC) scores (knee specific) as well as the Tegner score (activity level).¹⁰ Unfortunately, these scores have not been specifically validated in the multiligament knee.¹¹

Outcome Scores

The Lysholm score is a clinical score developed for the follow up of knee ligament surgery and is weighted toward the patients' subjective evaluation.^{11,12} A score between 0 and 100 is generated, allowing a rating of *excellent* (95 to 100), *good* (84 to 94), *fair* (65 to 83), or *poor* (< 65). The average Lysholm score in the normal, healthy population is 94,¹³ and this score has been demonstrated to be valid for a variety of knee injuries.¹⁴

Traditionally, the Lysholm score has been the most commonly employed measure in studies of MLKI and surgery. Mean postoperative Lysholm scores reported in surgically treated multiligament knees range between 84.3 and 85.2. In nonoperative groups, it ranges between 66.5 and 67.2.^{10,15} By comparison, Lysholm scores after ACL reconstruction range between 85 and 95.¹⁶ These spectra of scores, taken in the context of other knee injuries, highlight the devastating nature of the injury and the difficulty faced in trying to restore function with surgical treatment.

The IKDC Subjective Knee Evaluation Form score incorporates subjective, objective, and functional measurements, including patient symptoms, range of motion (ROM), ligament examination, functional tests, and X-ray findings.¹⁷ For this reason, Wascher et al described the IKDC as probably the best rating system for critically assessing the results of knee dislocation treatment.⁵ A score is generated on a scale

between 0 (*worst possible*) to 100 (*highest possible*). An evidence-based review by Peskun and Whelan showed that the overall proportion of multiligament knee injured patients achieving normal or nearly normal IKDC scores was 61.3%.¹⁰ By comparison, outcome analysis after reconstruction of isolated ACL injured patients suggests that between 78% (hamstring) and 80% (bone-patellar tendon-bone group) have class A or B final overall IKDC score.¹⁸

The Tegner score is a sport-specific activity level, quantifying activity from 0 to 10, where an individual competing in sports at an elite level has an activity level of 10, an individual participating in sports at a recreation level has an activity level of 6, and an individual on a disability pension due to knee problems has a level of 0.¹² The average Tegner activity level in the normal healthy population is 5.7.¹³ The aggregate average Tegner scores are 4.8 and 2.7 in operative and nonoperative cohorts, respectively.¹⁰ Some problems exist with this score because it relates activity to specific sports rather than specific function, and it has not been validated.^{11,19}

Other Outcome Measures

In broad terms, the spectrum of outcomes following MLKI encompasses those patients that have relatively stiff and painful joints as well as those who describe primarily residual instability and apprehension. The optimal outcome measure then would be one, which captures functional data from these seemingly disparate patient profiles while avoiding floor and ceiling effects. In the absence of such a measure, investigators often employ a broad range of outcomes designed to capture stiffness (ROM testing including contractures and flexion), laxity (KT-1000 measurement, Lachman test, Pivot shift test, posterior drawer test), return to activity (preinjury employment and preinjury sporting activity), and functionality (Lysholm, IKDC). The practice of using so many different outcomes can be costly and time consuming and lead to "responder burden" on behalf of study subjects.

No outcome measure has been previously validated for the use specifically in those patients with MLKI. Reviews of relevant outcome studies (in patients with multiligament injured knees) that have utilized both the IKDC and the Lysholm have revealed that there is often a discrepancy in functional outcome scores between these two measures. For example, in the retrospective series by Mariani et al,³⁹ individuals who underwent a repair or reconstruction of their ligamentous structures had an average Lysholm score of 85, which has been defined as "good." However, using the IKDC subjective score, only 25% of patients were able to achieve good or excellent results. Furthermore, there were no individuals in the repair group who were able to return to their preinjury level of sport.

Current instruments also lack the content necessary to evaluate patients with MLKIs. For example, the knee-specific instruments that have been published in the literature do not take into account the impact of neurological and vascular injuries as well as the impact of polytrauma on this subset of patients. There seems to be a need for the development of a disease-specific quality of life instrument that is reliable,

valid, and responsive and that can be used in patients with MLKIs.

Operative Versus Nonoperative Management

Four main studies have compared operative to nonoperative treatment; all are level III or IV retrospective cohorts.²⁰⁻²³ In the largest of these, Richter et al compared 63 patients treated with a combination of early and late surgery, to 26 patients treated nonoperatively. Statistically superior outcomes were demonstrated in the surgical group in terms of the Lysholm score (78.3 vs. 64.8), the Tegner score (4.0 vs. 2.7), IKDC activity level, Lachman test, as well as working ability and sports ability.^{22,24} **Table 1** lists the outcomes of the largest studies of operative and nonoperative treatment of MLKI.

The operative management of multiple ligament injuries, compared with nonoperative management, has been shown to result in superior clinical and functional outcomes in meta-analysis, systematic reviews, and evidence-based reviews.^{3,10,15,20} Studies comparing these two treatment options consistently show improved Lysholm scores, as well as higher rates of excellent and good IKDC scores with operative management.^{15,20-23,25}

In regard to ROM and contractures, an evidence-based review of articles published between 2000 and 2010 demonstrated no statistically significant differences between operative and nonoperative groups; however, there were statistically significant differences between the two cohorts in return to employment and return to sport.¹⁰ This is in contrast to a meta-analysis published in 2001 by Dedmond and Almekinders, which failed to show that return to pre-injury employment or athletic activity was improved by operative management.¹⁵ It may be that the 2001 study had insufficient numbers to detect a significant difference, or it may be that surgical techniques have improved over the last decade. Interestingly, in the review of 31 articles published between 2000 and 2010, the aggregate average Ly-

sholm scores were 84.3 and 67.2 for the operative and nonoperative cohorts, respectively. These are nearly identical to the average Lysholm scores published in 2001 for the operative and nonoperative groups (85.2 and 66.5).^{10,15}

Most surgeons with experience in MLKIs agree that operative management is likely the gold standard.²⁶ However, some indications for nonoperative management remain, including severe polytrauma, head injury, advanced age, medical comorbidities, poor patient compliance, and soft tissue compromise about the knee.¹⁰ Thus, despite evidence that operative management is superior, there will always remain a subset of patients for whom—usually due to coexistent injury or illness—nonoperative management is prudent. Moreover, the timing and extent of surgery may also require modification based on extenuating patient or injury factors. The nuances of nonoperative management vary greatly between authors and are discussed further later in the article.

Early Versus Delayed Surgery

Early surgery is usually defined as surgical repair or reconstruction performed less than 3 weeks after injury. Three weeks is thought to be the latest at which time damaged structures are still anatomically identifiable, with minimal tissue retraction, and able to accommodate suture repair. Recognizing that initial capsular healing may be advantageous to allow arthroscopic distension of the joint (and avoid the potential for fluid extravasation), the optimal window for surgery is likely between 10 and 20 days after injury.^{1,27} **Table 2** lists the outcomes of studies comparing early and late surgical management of MLKI. **Table 3** lists the largest studies looking at early, delayed, and two-stage surgery, respectively.

Results

Harner et al, in a retrospective study of 31 consecutive patients with a knee dislocation, compared 19 patients who were treated less than 3 weeks after injury, and 12

Table 1 Operative versus nonoperative treatment of MLKI: Study characteristics

Treatment	Authors	No. knees	Year	Age	Lysholm	IKDC	ROM	Contracture	RTE, %	RTS, %
Operative	Engebretsen et al ²⁴	85	2009	33	81	64	NR	NR	NR	NR
	Hirschmann et al ⁶¹	68	2010	30	83	58	125	2	82	NR
	Richter et al ²²	63	2002	33.5	78.3	NR	NR	11% > 5	85	56
	Tzurbakis et al ²⁹	48	2006	28.6	NR	77	129.9	1.6	NR	NR
	Fanelli and Edson ³⁴	35	2002	NR	91.2	NR	NR	NR	NR	NR
	Karataglis et al ³⁵	35	2006	35.1	NR	NR	118.4	3.1	91	46
Nonoperative	Richter et al ²²	26	2002	33.5	64.8	NR	NR	24% > 5	53	17
	Plancher and Siliski ²³	19	2008	26	70.5	NR	107.5	3.8	69	31
	Wong et al ²⁰	11	2004	22	NR	63.7	136.8	1.8	NR	NR
	Ríos et al ²¹	5	2003	34.2	NR	NR	NR	NR	NR	NR

Abbreviations: IKDC, the International Knee Documentation Committee (% Excellent/Good); MLKI, multiple ligament knee injury; NR, not reported; ROM, range of motion; RTE return to employment; RTS return to sport.

Table 2 Early versus delayed surgery for MLKI: Summary of comparative studies

Surgery	Authors	No. knees	Year	Age	Lysholm	IKDC	ROM	Contracture	RTE, %	RTS, %
Early	Tzurbakis et al ²⁹	35	2006	29	88.3	77.1%	129.5	1.6	NR	NR
	Harner et al ²⁸	19	2004	29	91	52.6%	128	NR	NR	NR
	Fanelli et al ²⁶	10	1996	NR	90	NR	NR	NR	NR	NR
	Wascher et al ⁵	9	1999	26	92	44%	132	2.2	NR	NR
	Liow et al ³⁰	8	2003	26	87	37.5%	NR	10	NR	NR
	Delayed	Tzurbakis et al ²⁹	9	2006	29	81.7	55.5%	131.7	1.4	NR
Harner et al ²⁸		12	2004	29	80	8.3%	129	NR	NR	NR
Fanelli et al ²⁷		11	1996	NR	91.6	NR	NR	NR	NR	NR
Wascher et al ⁵		4	1999	31	79	50%	126	4.9	NR	NR
Liow et al ³⁰		14	2003	27	75	35.7%	NR	7	NR	NR

Abbreviations: IKDC, the International Knee Documentation Committee score (% Excellent/Good); MLKI, multiple ligament knee injury; NR, not reported; ROM, range of motion; RTE return to employment; RTS return to sport.

patients managed with late reconstruction.²⁸ The mean Lysholm score was 91 points for the acutely reconstructed knees and 80 points for the chronically reconstructed knees, a trend that approached statistical significance ($p = 0.07$). According to the final overall IKDC rating, no knee in either group received a normal overall IKDC rating. Of the 11 "nearly normal knees," all but 1 knee was treated acutely.

Tzurbakis et al retrospectively compared 35 early against 9 late surgical interventions, finding a statistically significant improvement in Lysholm score in the operative group.²⁹ In the three other studies comparing early and late surgical treatment of the multiligament knee, no statistically significant difference in knee outcome scores has been demonstrated; however, there is a trend toward better outcomes in the acute treatment.^{5,27,30} Unfortunately, the patterns of injury and the surgical treatment vary in various studies.

Levy et al, in a systematic review, showed that early surgical treatment resulted in higher mean Lysholm scores and a higher percentage of excellent and good IKDS scores (47 vs. 31%) than delayed surgery.³ No significant difference was seen in mean ROM or flexion, but patients treated with early surgery had statistically higher sports activity scores.

A systematic review by Mook et al in 2009 found that acute treatment of knee dislocations led to increased anterior instability compared with chronic treatment. No statistically significant difference was detected with posterior instability or varus or valgus laxity based on surgical timing.² The same study also demonstrated that acute treatment is more likely to result in flexion loss of more than 10 degrees versus chronic treatment. This difference was more pronounced when patients were immobilized in the postoperative period. In addition, the number of patients requiring manipulation

Table 3 Early (< 4 weeks) versus delayed surgery (> 4 weeks) versus 2-stage for MLKI: Study characteristics

Surgery	Authors	No. Knees	Year	Age	Lysholm	IKDC	ROM	Contracture	RTE, %	RTS, %
Early	Ibrahim et al ⁶²	41	1999	26.3	79.2	NR	125	NR	NR	NR
	Owens et al ³¹	28	2007	35	89	NR	119.3	1.9	71.4	NR
	Yeh et al ⁶³	25	1999	37.8	84.1	NR	129.6	1	91.3	NR
	Ibrahim et al ⁶⁴	20	2008	27.3	91	45%	NR	20% > 5	NR	NR
Delayed	Fanelli and Edson ⁶⁵	41	2004	NR	91.7	NR	NR	0	NR	NR
	Levy et al ⁴⁵	18	2010	NR	88	77	115	NR	NR	NR
	Strobel et al ⁴⁴	17	2006	30.7	NR	29.4%	NR	12% > 5	NR	NR
	Zhao et al ⁶⁶	14	2008	27	92.7	87.4	NR	0	NR	28.6%
	Lo et al ⁶⁷	11	2009	33	88	82%	NR	NR	NR	NR
	2-stage	Bin and Nam ⁶⁸	15	2007	30.4	87.6	73.3%	NR	NR	NR
Ohkoshi et al ⁶⁹		9	2002	28.7	NR	NR	139.5	0	NR	NR
Levy et al ⁴⁵		10	2010	NR	85	79	130	NR	NR	NR

Abbreviations: IKDC, the International Knee Documentation Committee score (% Excellent/Good); MLKI, multiple ligament knee injury; NR, not reported; ROM, range of motion; RTE return to employment; RTS return to sport.

under anesthesia or operative arthrolysis was increased in the acute treatment group. Staged treatment (defined as a combination of repair and reconstruction, in both the acute and chronic setting) resulted in superior subjective outcomes than acute and then chronic treatment.²

It should also be emphasized that, in comparing early and delayed surgical groups, the latter likely had symptoms necessitating further intervention, a fact which imposes an inherent bias in patient selection and assessment of outcomes. There is likely a subset of patients in the early group that may have done well without surgery (or with a delayed approach). This is likely not the case for the delayed groups in which (given the treatments were not randomly allocated) all patients required surgery to address ongoing and intolerable symptoms. A well-designed randomized trial would likely help eliminate this potential bias and go a long way to answering the question of when we should be intervening with surgery in the multiligament injured patient.

Conclusion

The limited data available would seem to suggest that early surgical intervention affords the best opportunity to maximize outcome following MLKI. There are some challenges to getting the acutely multiligament injured knee to surgery within a 3-week window. Some knee dislocations present late because the knee spontaneously reduces and the injury to the knee is underestimated. In addition, there can sometimes be no effusion due to the capsular disruption, further hampering timely recognition of the extent of the injury. In addition, concomitant injuries can prohibit early surgery, including open knee dislocations, vascular injuries, and associated head, abdominal or chest trauma, for which the best approach may be delayed surgery.²⁸

The studies thus far have failed to conclusively prove that early surgery is superior, but there are clear trends toward improved outcome with early surgery, likely due to the easier identification of anatomy, as well as the ability to primarily repair some structures without having to overcome significant retraction or tissue atrophy that can occur with delay. All of these studies are underpowered and thus unlikely to show significant differences; the variety of injury patterns and surgical techniques used also limits the ability to make definitive conclusions.

In the future, early repair (with or without reconstruction) and chronic reconstruction will likely need to be considered as separate entities in investigations on MLKIs. On the basis of the available evidence, a multicenter prospective cohort should likely aim to operate on all knee dislocations early. When mandated by associated injury or delayed recognition, late reconstructions would form a separate study group.

Repair Versus Reconstruction

Most surgical techniques described for treating MLKIs describe either repair of the torn structures or reconstruction with allograft, autograft, or synthetic ligaments, or combinations thereof. Apart from graft choices, reconstructive options include a variety of surgical techniques across very heteroge-

neous groups of patients. Few comparative studies are available. In general, two philosophies of surgical treatment dominate the literature: early repair versus delayed reconstruction.

Anterior Cruciate Ligament/Posterior Cruciate Ligament

Owens et al performed open primary repair of ligaments in 30 consecutive knee dislocations within the first 2 weeks, including primary repair of ACL and PCL. A mean postoperative Lysholm score of 89 was reported, with minimal permanent loss of ROM and good stability.³¹ The lack of comparison with cruciate reconstruction is problematic and many surgeons would feel unfamiliar with open repair in the age of reconstruction. Although the likelihood of encountering a cruciate ligament avulsion fracture amenable to direct repair is increased in the setting of knee dislocation, the incidence of stiffness has been suggested to be greater when directly fixing ACL avulsions.^{32,33} Furthermore, the long-term results of repairing isolated ACL injuries were generally thought to be inferior to modern reconstructive techniques.

Reconstruction of both the ACL and PCL has become popular, with good outcomes reported using autograft, allograft, and synthetic ligaments.^{5,28,34-36} Fanelli and Edson³⁴ reported on the 2- to 10-year results of 35 arthroscopically assisted combined ACL and PCL reconstructions with various grafts. Normal Lachman and pivot shift test results were found in 33 of 35 (94%), whereas a normal posterior drawer/tibial step-off was found in 16 of 35 (46%) knees.³⁴ PCL reconstruction has been described using both single and double bundles, as well as inlay versus transtibial techniques.^{27,28,35,37,38}

Mariani et al looked at the outcome in groups of patients with ACL and PCL injuries with three surgical techniques: both cruciates repaired, both cruciates reconstructed, or ACL reconstruction combined with PCL repair.³⁹ All three groups had very similar IKDC and Lysholm scores. It was noted that direct repair of both cruciates had statistically significant increased rates of posterior sag and lower rates of return to preinjury level, whereas the group of patients in whom both the ACL and the PCL were reconstructed had increased return to sport rates.

Posterolateral Corner

It has been demonstrated that a combined reconstruction of the PCL and PLC is superior to PCL reconstruction alone,⁴⁰ and it is generally accepted that the avulsed LCL from the femur and fibula, and the popliteus tendon from the femur, may be directly repaired.^{24,28,35} In addition, direct repair of the PLC via en bloc advancement has been advocated by Shelbourne et al, with good results being reported: 15 of 17 patients had normal lateral laxity, and the mean IKDC score was 91.3.⁴¹

There are a multitude of reconstruction techniques of the PLC described, including biceps femoris tenodesis, synthetic LCL reconstruction, and reconstruction of midsubstance popliteus tears.^{27,28,35,36} Reconstructing the PCL with Achilles tendon allograft and using a biceps femoris tendon tenodesis to reconstruct the PLC in 41 patients with chronic injuries,

Fanelli et al reported postoperative mean Lysholm scores of 91.7, and Tegner scores of 4.92.²⁷ Some of the most popular reconstructions recently have involved the use of two-tailed allografts: The Larsen technique reconstructs the LCL and the popliteofibular ligament, and the LaPrade "anatomic" technique reconstructs the LCL and the popliteofibular ligaments with the addition of a static "popliteal bypass" in an attempt to replicate the popliteus tendon.⁴²⁻⁴⁴

Direct comparisons of repair versus reconstructive approaches to high-grade lateral/posterolateral injuries have been recently published. In 57 knees, Stannard et al could not detect a statistically significant difference in Lysholm, IKDS scores, or return to work rates between the two groups.⁴³ However, return to sport and objective stability was increased in the reconstruction group, leading the authors to recommend reconstruction as opposed to repair. In a consecutive series of patients with PLC injuries, Levy et al initially repaired laterally sided injuries before moving to ligament reconstruction. The 40% (4 of 10) failure rate in the repair group was reduced to 6% (1 of 18) failure rate in the reconstruction group.⁴⁵

Medial Collateral Ligament

No direct prospective comparison of repair versus reconstruction of the medial collateral ligament (MCL) exists.²⁶ The MCL is often repaired in the setting of knee dislocation, either with direct suture of midsubstance tears or by repair of femoral or tibial-sided avulsions.²⁸ Fanelli et al recommended repair of insertions if possible, with the use of an Achilles tendon allograft to reconstruct the MCL as required.²⁶ Owens et al preformed primary repair of complete MCL avulsion in 11 patients with knee dislocation, with excellent valgus stability reported in all patients.³¹ However, in a series of 73 knee dislocations with a posteromedial corner injury, the failure rate was 20% (6 of 24) in the repair group and 4% (2 of 48) in the reconstruction group.⁴⁶

Conclusion

Reasonable results have been reported with both early repair and early reconstruction. In the setting of LCL, popliteus, and MCL avulsions, direct repair is a technically viable option. Recent evidence exists, however, that reconstruction may still be the preferred technique. Most experienced multiligament surgeons would agree that ACL and PCL reconstructions are the best option for bicruciate injuries and the—albeit limited—literature seems to support this opinion.

Controversy continues as to the optimal management of high-grade collateral ligament injury. Various reconstruction techniques for the PLC exist, and their respective roles in reconstruction of the multiple injured knee are subject to debate.^{27,40,41,47} The optimal approach is elusive but may involve some combination of the two philosophies: anatomic repair performed in a timely manner and splinted with a concomitant reconstructive procedure. Such an approach affords the restoration of normal anatomic attachments provided by repair, with the added stability of the reconstruction to allow early motion and potentially prevent arthrofibrosis.

Autograft Versus Allograft

So many combinations of different autografts and allografts are described in the multiligament injury literature, in various reconstruction techniques, that attempting to differentiate outcomes is nearly impossible. Allograft is a very popular choice for reconstruction in the multiple-ligament injured knee given the extreme insult to the joint and its soft tissue envelope at the time of the trauma. Most surgeons are hesitant to inflict further damage by harvesting autograft tissue in this setting. Moreover, the integrity of autograft tissue may be compromised in the recently dislocated knee. Allograft sterility and patient safety are tantamount concerns; however, debate over the optimal preparation of allograft tissue continues and maintenance of structural integrity being weighed against complete eradication of potential pathogens. Allograft is unavailable in many countries and centers. In other places, the cost of procuring the grafts may be prohibitive. For those surgeons who do employ allograft in the treatment of MLKIs, it mandates a specific conversation with patients outlining its necessity and potential risks.

The issue of autograft versus allograft is likely another question that will only be effectively answered by a multi-centered study; however, it may be clouded by variability in reconstructive techniques. In the first instance, a consensus regarding graft choice may be an important step in study design as would standardization of graft preparation and reconstruction construct.

Postoperative Rehabilitation

Rehabilitation is an important aspect of the treatment of knee dislocations after surgery and protocols described in the literature vary. The difficulty lies in achieving a balance between early immobilization to prevent stiffness and immobilization to promote healing and stability.

The systematic review by Mook et al suggested—seemingly paradoxically—that immobilizing knees after acute surgery for knee dislocation led to increased posterior instability versus a protocol of early mobilization. This trend was also seen in the incidence of postoperative varus and valgus laxity.² These (statistically significant) findings would suggest that early mobilization was key to stability; however, within the chronic treatment group's varus laxity was increased with early mobilization.

Furthermore, the same systematic review showed that immobilization after acute surgical treatment of knee dislocations increased the incidence of both flexion loss more than 10 degrees and extension loss more than 5 degrees.² These same patients were significantly more likely to have severely abnormal or poor outcomes and were significantly less likely to return to work.

Richter et al in 2002 compared 6 weeks of immobilization to functional rehabilitation, (flexion to 60 degrees allowed after 48 hours), in patients managed both operatively and nonoperatively.²² Statistically significant improvements were seen in the Lysholm and Tegner scores but not in the IKDC scores in patients treated with functional rehabilitation.

The use of postoperative hinged knee external fixation device is being compared with a hinged knee brace in a prospective randomized study of knee dislocations. Early results suggest reduced instability and reduced surgical failure rates with the use of a hinged external fixation after ligament reconstruction.⁴⁸

A randomized comparison of early versus delayed rehabilitation protocols following acute (< 3 weeks) multiligament surgery would be possible, but again subject to the issue of heterogeneity amongst patterns of injury and repair techniques. Given the more recent popularity of combined early repair and reconstruction, early motion may be a more favorable option to surgeons who in the past had been hesitant to mobilize acutely repaired tissues.

Other Confounding Factors

Open Knee Dislocation

Between 5 and 17% of all knee dislocations are open, and the management of the joint injury is made more complex by the requirement for immediate surgery (irrigation and debridement) to render the soft tissues envelope sterile.⁴⁹ External fixation might be considered to assist with wound stability in this setting and muscle flap and/or skin graft coverage is often necessary. Furthermore, patients with open knee dislocation often have associated injuries in addition to wound issues and severe ligament injuries. These include multiple fractures as well as vascular and nerve injuries.⁵⁰ Given the degree of trauma required to disarticulate the joint and cause concomitant disruption of the skin and surrounding soft tissue, the open knee dislocation should be thought of as a "near-complete" traumatic amputation and treated accordingly.

King et al reported on seven patients with open knee dislocations, treated with external fixation and multiple wound debridements; ligament reconstruction was performed once wounds were sufficiently healed.⁴⁹ The infection rate was 43% and one patient required an amputation for infection. *Good to excellent* results were seen in only 33% of patients using 12 Item Short Form Health Survey outcome score. Wright et al reported on 19 open knee dislocations.⁵⁰ Of the 19 patients, 9 (47%) had neurological or vascular injury; 5 of these patients had complete vascular disruptions requiring emergency surgery and 2 patients ultimately required amputation.

Although there are limited data, it would be reasonable to conclude that open knee dislocations have a higher likelihood of poorer outcomes and the potential for limb-threatening complications. Open knee dislocations should not be excluded from a multicentered trial, but given the poor prognosis, they should likely be analyzed separately.

Fracture Dislocation

Most commonly unstable in association with tibial plateau fracture, knee fracture dislocations are challenging to diagnose and treat. The incidence is likely higher than previously expected. Magnetic resonance imaging review of 103 high-energy tibial plateau fractures found that 53% had multiple torn ligaments.⁵¹ A staged treatment protocol has been advo-

cated by Stannard et al, with fixation of the fracture as required after soft tissues have settled and staged reconstruction of the cruciates and PLC at 4 months postinjury to allow for tibial bone healing. Delay is because the failure rate of early PLC reconstruction is reported at more than 30% in this setting.^{43,52} The staged protocol achieved an average Lysholm knee score of 86 points in a series of 54 fracture dislocations.⁵³

Vascular Injury

Between 8 and 22% of patients with a knee dislocation have a vascular injury that requires surgical repair; this is slightly higher in patients with open knee dislocations.^{49,50} A report by Patterson et al from the LEAP Study Group reported on 18 patients with knee dislocation and an associated popliteal artery injury. Four patients ultimately needed amputation and a moderate to high level of disability was seen 2 years after injury.⁵⁴

Case series detailing patients with vascular injury in association with knee dislocations are striking for the high incidence of associated injuries, especially open wounds and nerve palsies.⁵⁵ Treatment algorithms also need to be adjusted in this setting, with nonoperative strategies or the use of external fixation being considered more often. It seems reasonable to conclude that a vascular injury predisposes the patient to a higher risk of a poor outcome and that these patients should also be considered as a separate subgroup in a larger prospective study.

Nerve Injury

Rates of injury to the common peroneal nerve after knee dislocation vary, with 25% reported in one series. Complete recovery was seen in 21%, partial recovery in 29%, and no useful recovery in the remainder.⁵⁶ Although the velocity of trauma and degree of ligament disruption would seem to be increased in patients with nerve injury, male gender, increased body mass index (BMI), and fibular head fracture have also been associated with increased incidence.^{57,58} Up to half of these nerve palsies will not recover and the surgical options are limited; nerve injuries undoubtedly contribute to poorer outcomes after knee dislocation.^{58,59} In those patients whose nerve injury does not recover, gait disturbance can have a profound effect on lower extremity outcomes and functional scores.

Obesity

Interestingly, Azar et al presented a case series of patients presenting with low-velocity knee dislocation. All of the patients were clinically obese with an average BMI of 48; 7 of these patients had popliteal artery injuries requiring repair.⁶⁰ Outcomes in patients managed with surgical reconstruction were fair, suggesting that obesity predisposes to severe injury and poor outcome, even after a low velocity injury.

Discussion

One of the greatest barriers to assessing the outcome of treatment of the multiple ligament injured knee is the

heterogeneous nature of the anatomical knee injury patterns, in combination with the relatively rarity.³ This, coupled with the variety of treatment options available, has made reaching definitive conclusions difficult. Despite the need to treat more severe knee dislocations differently, they are often reported in the literature together with less-severe disruptions.²

A review of 31 articles describing the operative management of MLKIs published between 2000 and 2010 is striking for a few things: the young average age of patients (mean 30.5), the limited numbers in each study group (8 to 89), and the relatively poor quality of all studies based on the News-Team-Ottawa score (mean 3.0, range 1.5 to 4.5).¹⁰ The majority are retrospective case series, with a few comparative studies. In fact, the total number of knee dislocations included in this evidence-based review was only 926. All of the studies looking at the treatment of knee dislocation suffer from low numbers.²²

To offset the rarity and heterogeneity seen in this population group, the optimal vehicle for future research is undoubtedly a multicenter effort, where large patient volumes can be assimilated across the entire spectrum of injury patterns and treated by experienced surgeons.¹

Conclusion

1. *Operative versus nonoperative treatment.* On the basis of available evidence, it would seem reasonable to conclude that patients treated operatively, if their condition allows, demonstrate superior outcomes versus nonoperatively treated patients.
2. *Early versus late surgery.* Currently available evidence suggests that patients treated early (< 3 weeks) have improved outcomes. There are certain confounders that must be considered, however: most studies are not randomized, and it is likely that patients with more severe injuries, both of the knee and of the patient, are treated with delayed surgery.³ It may also be that patients treated on a delayed basis have persistent symptoms that necessitate surgical intervention. The impact of these confounding factors would be optimally addressed by a prospective investigation randomizing patients to early versus delayed surgery.
3. *Repair versus reconstruction.* Several recent prospective studies have demonstrated unacceptable high failure rates with isolated repair of damaged collateral ligaments. Although delayed reconstruction demonstrates improvements over early repair, the optimal strategy is likely one where both early repair and reconstructive techniques are combined to allow immediate stability and early mobilization.
4. *Outcome measures.* A variety of both knee-specific scores and generalized patient scores have been used in previous studies. The nonuniform use of outcome measures makes comparison between studies very difficult. Clearly defining which knee outcome scores to use will be a central component of multicentered research in this field. Given the extent of the injury and the high rate of associated local and systemic trauma, the development of multiligament-

specific quality of life measure will be an important tool in the understanding of outcomes after knee dislocation.

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